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PETROGRAPHICAL CHARACTERISTICS OF THE GYÓD SERPENTINITE BODY, SOUTH–EASTERN TRANSDANUBIA

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ABSTRACT

The Gyód serpentinite body consists mainly of serpentinite, in addition, ultramafics and tremolite, anthophyllite schists are also present. Based on textural investigations the relic enstatite and olivine–bearing ultramafics constrain a harzburgitic protolith for the serpentinites. Low CO_2–content fluids penetrated the body and serpentinised the, resumably, ocean mantle-derived, depleted harzburgites. The serpentinization resulted in a new, lizardite, chrysotile–magnetite–talc–chlorite mineral assemblage. The tremolite and anthophyllite schists occur just certain parts of the sequence suggesting that their development was caused by localised impacts. The tremolite could have formed from a higher CO_2–content fluids. The anthophyllite schists appear adjacent to the aplite dyke which, locally, thermally metamorphosed the serpentinite. The formation of bastites after talc, tremolite and anthophyllite demonstrates that serpentinization is a multi–stage process. Subsequently, carbonate minerals were formed.

INTRODUCTION

In the search for radioactive substances geophysical reconnaissance work started in the early 1960s in southern Transdanubia. Field magnetic, aerogamma and aeromagnetic investigations indicated strong magnetic anomalies in the crystalline basement and, subsequently, some of these anomalies were penetrated by boreholes (boreholes of G–2 and He–1,–2). This resulted in the discovery of a serpentinised body in the region of Gyód and Helesfa. In the 1970s and 1980s more detailed research was carried out on the Gyód serpentinite to identify its mineralogy and geochemistry. Attempts were also made to determine the protolith and the metamorphic evolution-path of the serpentinite. These results are, in many cases, contradictionary. The aim of this paper is to clarify the mineralogy and texture of the sequence penetrated by the Gyód–2 borehole.

PREVIOUS WORKS ON THE GYÓD SERPENTINITE BODY

According to SZEDERKÉNYI (1974a,b, 1976, 1977) the Lower Paleozoic Gyód serpentinite can be regarded as a vertical neck or dyke, representing the root–remnant of an ancient volcanic event. The main part of the body consists of pyroxenite, weakly

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serpentinised pyroxenite and serpentinite, all of them showing a laminar texture, caused by the lineation of large clinopyroxene crystals. This rock assemblage was later cut by Carboniferous aplite–microgranite veins. The composition of the pyroxenite is predominantly clinoenstatite a smaller quantity of olivine, basic plagioclase and chromite–magnetite. The ferromagnesian suite was altered to lizardite and clinochrysotile during serpentinization. The microstructure of the serpentinised rocks exhibits an undisturbed mesh structure without traces of any shearing or cataclasis.

ERDÉLYI (1974), using X–ray analysis on particular mineral concentrates, attempted to reconstruct the complex metamorphic evolution of the Gyód serpentinite. He invoked a hot basic magma intrusion into a serpentinised rock complex which transformed lizardite to olivine and enstatite above 800°C, while talc and clinoenstatite were generated from enstatite above 700°C. With further cooling chlorite was formed between 500–600°C whereas the serpentine minerals (mainly lizardite and chrysotile) were crystallised around 400°C. He also detected dolomite, ankerite, calcite, brucite, boehmite, montmorillonite, apatite, tourmaline, muscovite, biotite, magnetite and plagioclase feldspar (albite, bytownite). He concluded, that the protolith of the serpentinite was probably an olivine–rich ultramafic rock such as olivine–diabase.

GHONEIM (1978) distinguished three rock types in the Gyód rock complex including pyroxenite, amphibolite and serpentinite. According to his results the pyroxenite consists of 75 % clinoenstatite, 7 % olivine, 16 % basic plagioclase and 2 % opaque minerals. This composition is in agreement with the results of SZEDERKÉNYI (1977). Hornblende is the dominant mineral in the amphibolite, accompanied by minor amounts of quartz, plagioclase and laminar serpentinite (bastite). Chrysotile and lizardite builds up the mesh texture after olivine. Opaque minerals are chromite, magnetite and pentlandite. The presence of relic minerals suggests that the original rock might have been lherzolite and pyroxenite which were slightly serpentinised.

BALLA (1983, 1985) recognised four metamorphic events. The olivine and enstatite–bearing oceanic harzburgite underwent a granulite facies metamorphism (T>700°C), followed by an amphibolite facies cataclasis (T=600–650°C) which resulted in the formation of an enstatite$_2$–antophyllite–talc–magnetite paragenesis. A subsequent greenschist facies metamorphism produced antigorite, talc$_2$, magnetite and carbonate. During the final stage with serpentinization (T=200–300°C) lizardite, chrysotile and iddingsite were developed. According to his tectonic interpretation the serpentinite body was formed by the Upper Devonian–Lower Carboniferous collision of an older continent with island arc and obduction, followed by a post–collisional thermal and isostatic equilization which moved it into its present position.

PAPP (1989), using a microscope, an X–ray powder diffraction, and transmission electron microscope, carried out a detailed investigation of the serpentine minerals of the Gyód body and identified lizardite with little clinochrysotile and polygonal serpentine as the main serpentine minerals. Common accessories include chlorite and magnetite. The appearance of talc indicates the impact of the granite–aplite and veins. The serpentinite shows a dominantly pseudomorph texture but some altered, non-pseudomorphic texture can also be recognised.

GEOLOGICAL SETTING

The Gyód magnetic anomaly is situated along the Szilvás–Keresztespuszta–Aranyosgadány line with 5–7 km in length and 300–500 m in width. The strike of the diapir–like body is WNW–ESE and is similar to that of the country–rocks (*Fig. 1*). The geometric depth of the body is 400 m and it wedges out no deeper than 700–800 m. The borehole of Gyód–2 was drilled into the geometric centre of the serpentinite body, penetrating it between 65.2–131.3 m under the overlying Pleistocene and Lower Pannonian sediments (*Fig. 2*). The boreholes of Gyód–3 and Gyód–4 were drilled into the country–rocks which are mainly amphibolite and gneiss. However, Gyód–4 did not reach the proximity of the serpentinite contact which is probably in a tectonic zone.

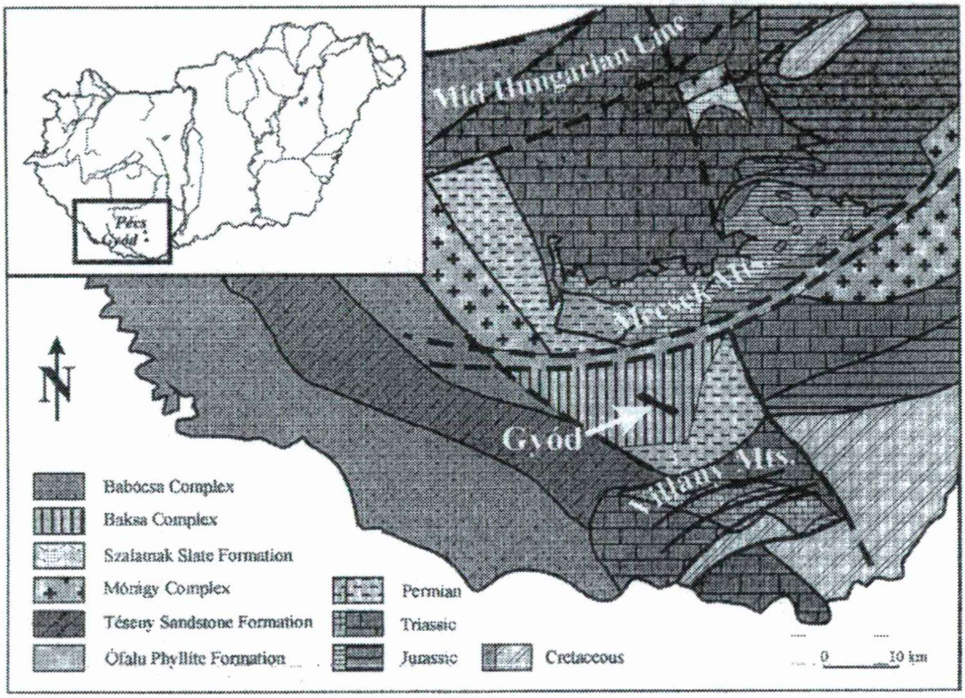

Fig. 1 Geological sketch map of South Transdanubia showing position of Gyód serpentinite (after SZEDERKÉNYI, 1994b and CSÁSZÁR, 1997).

TEXTURAL CHARACTERISTICS OF THE SERPENTINITE BODY

A new set of samples were collected for the current study from the entire Gyód–2 borehole sequence. These were examined both by macroscopy and microscopy, together with the previously analysed samples. According to the macroscopic observations three rock types could be distinguished: serpentinite, an ultramafic rock and an amphibole schist. 150 pieces of thin sections were described which were made from almost every metre of the serpentinite body in borehole. Detailed textural investigations permitted the subdivision of the three main rock types into the following:

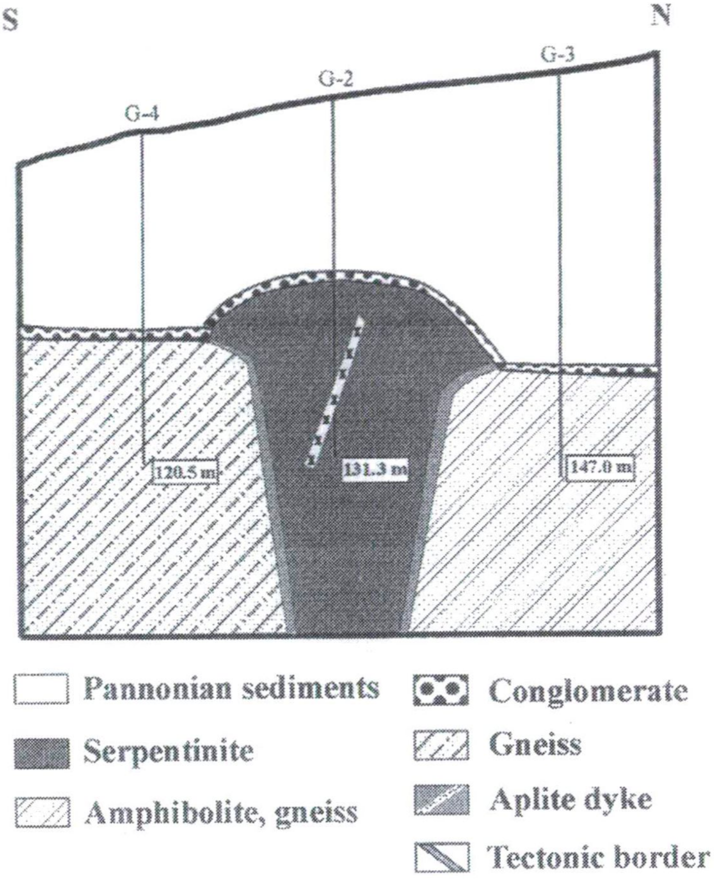

Fig. 2. Position of Gyód serpentinite within the sketchy cross–section.

Serpentinite

The Gyód body comprises mostly serpentinite which, according to structural characteristics and mineral composition is made up of several types, such as ultramafic rocks, amphibole schists and an aplite dyke which is known only from the borehole log (c.f. SZEDERKÉNYI, 1977). It may compartmentalise into the following types:

– between 65.2–68.1 m, in the uppermost part of the examined body a strongly sheared, tectonised serpentinite can be found which is cut by white and greenish carbonate veinlets. Oriented silvery grey mica grains can be recognised in it (*Fig. 3a*).

– between 70.0–78.6 m a massive dark grey serpentinite is intermingled with lighter grey units (*Fig. 3b*). This pattern resembles a cataclastic texture where the clasts appear to be the darker units, showing a mesh texture of serpentine minerals and magnetite. The lighter units represent the matrix which contains talc, chlorite, little serpentine minerals and minor amount of opaques. The mesh texture is often irregular because its centre is not well developed, instead of it short bipartite mesh and rim-like stages occur in a so called curtain texture (WICKS and WHITTAKER, 1977). This can be interpreted as an alteration of the mesh texture by shearing.

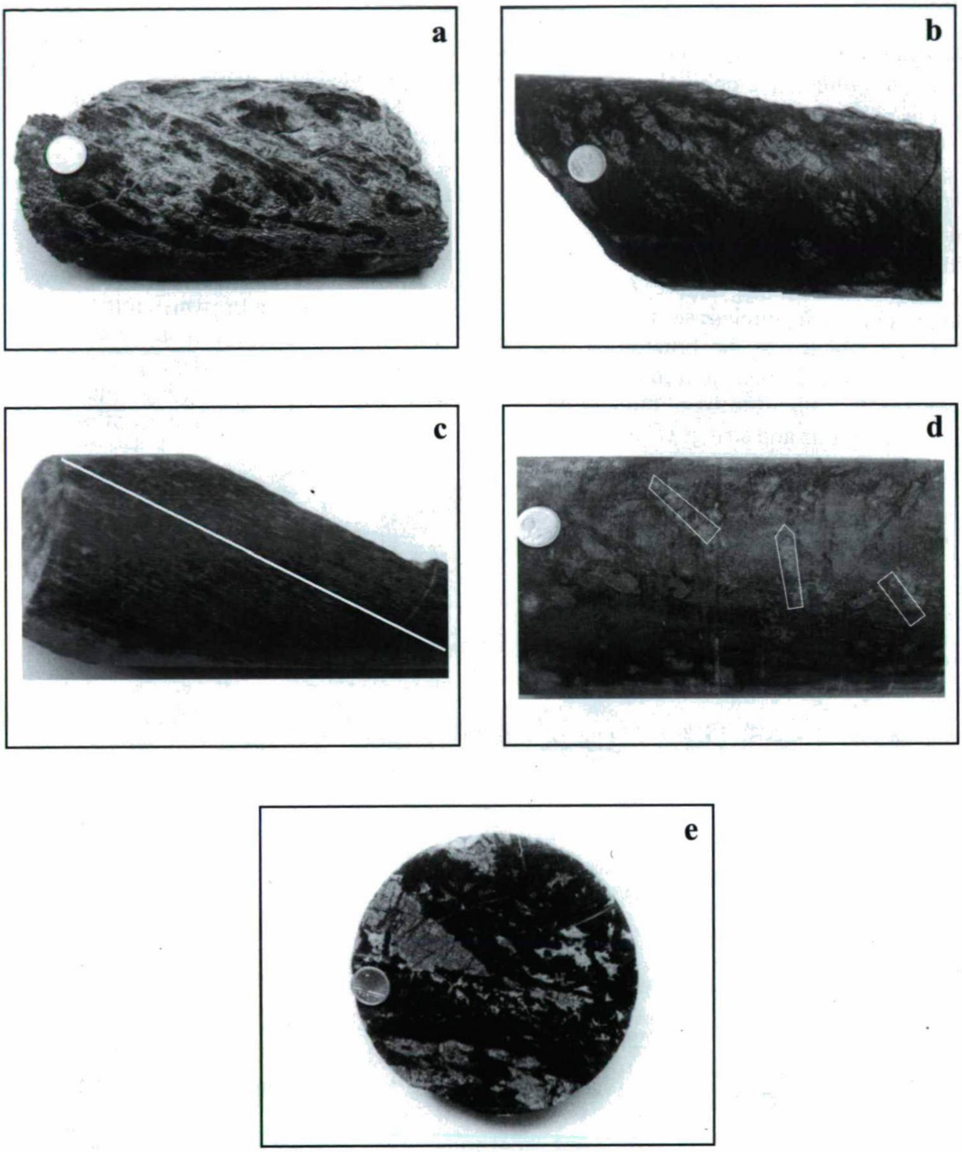

Fig. 3. The main rock types of the Gyód serpentinite (the size of the coin is 1.5 cm). a, ÁGK–7004 sample. Strongly sheared serpentinite from the uppermost part of the body; b, ÁGK–7017 Cataclastic serpentinite; c, ÁGK–7019. Serpentinite with 60-80 degree foliation plane (white line represents the foliation); d, ÁGK–7037 Non–foliated, bastite–bearing serpentinite; e, ÁGK–7083B Relic ultramafic rock (light) in serpentinite (dark).

– between 85.3–131.3 m a greenish dark grey serpentinite with 60–80 degree foliation can be found (*Fig. 3c*). Greenish-white, several mm wide veins cross cut it. The wider veins are complex, built up by alternating layers of serpentine and carbonate. Silvery, 1–2 mm sized micas (chlorite and/or talc) are abundant in the plane of foliation. 2–4 cm long oil green, columnar amphibole or enstatite–bastite with unctuous lustre occurs in them without any orientation. There is a non–foliated, massive serpentinite in this part of the drilling sequence which contains the same minerals as the previous type but they occur in smaller proportions (*Fig. 3d*).

The main rock–forming minerals of the serpentinites are lizardite, chrysotile magnetite, chlorite and/or talc, and/or carbonate, similar to those identified by PAPP (1989). Their textural features are as follows: The serpentine minerals appear in three textural units (i) in the mesh or mesh–like texture, (ii) in the pseudomorphs and (iii) in the veins. The mesh centre contains featureless serpentine. In the upper part of the mass a brownish mineral can be found which may be brucite (WICKS et al., 1977), however, its minute size would necessitate a high–precision microanalytical equipment for its accurate identification. The mesh rim is a bipartite type, built up by an α-serpentine. The central parting consists of magnetite grains and strings (*Fig. 4*). The relationship between the distribution of magne-

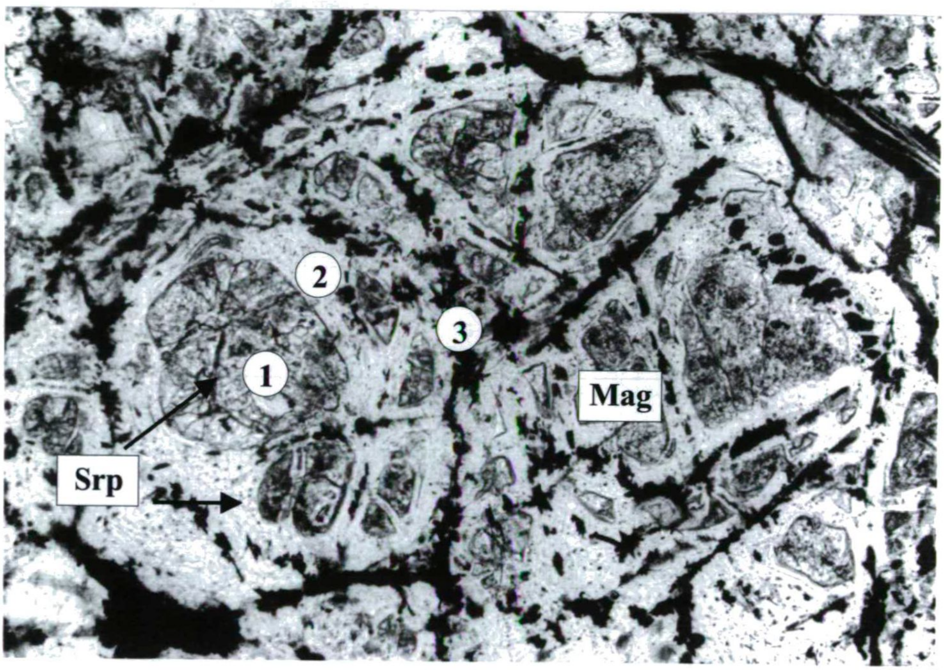

Fig. 4. No. 400412 sample. The basic unit of mesh texture from 79.7 m, 1. mesh centre, 2. mesh rim, 3. central parting, |N, 100x (The abbreviations were introduced by KRETZ (1983)).

tite grains and the ratio of serpentinization is well-documented (e.g. WICKS, WHITTAKER, 1977). Fine discrete grains of magnetite become coarser as the serpentinization progresses, concentrating in the mesh centre and in the central parting from which they migrate out into the cross–cutting lenses and veinlets at later stages. The second type of serpentine minerals occur as pseudomorphs (*Fig. 5*). Orthopyroxene, amphibole and talc–bastites are present in the whole sequence of the borehole. The altered, columnar enstatite type is similar to the bastite after amphibole. The original minerals of bastites cannot be determined accurately under the microscope (DUNGAN, 1979, WICKS, WHITTAKER, 1977). The serpentine pseudomorphs consist of χ–serpentine which is usually fibrous, but may also appear in form of nearly featureless plates. The final appearance of the serpentine minerals is in the cross–cutting veins. The thickness of the veins is between 0.1 mm and 4 cm. The simple veins contain fibrous χ–serpentine which is chrysotile, as revealed by XRD analysis. Carbonate and serpentine minerals can also be recognised in the complex veins.

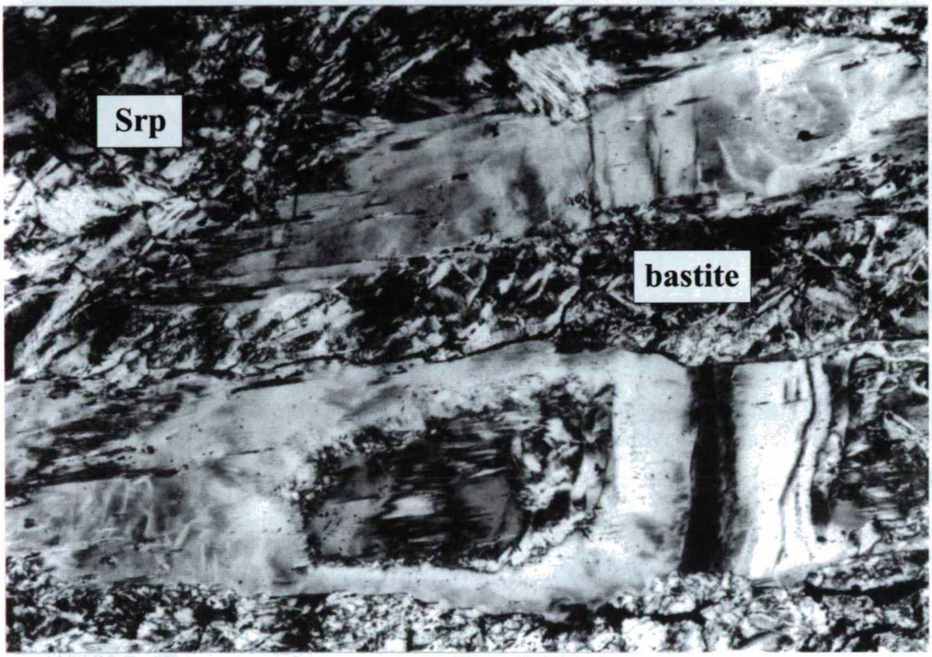

Fig. 5. No. 400398 sample. Bastites with altered texture from 98.0 m, +N, 50x.

Hypidiomorphic chlorite, with an average 0.2 mm size, is a rather frequent component in all rock types. Its crystals are often deformed and are optically zoned. Carbonate minerals are common in the cleavage faces of the chlorite and are rarely surrounded by opaque minerals. An altered, xenomorphic chlorite also occurs within the serpentine minerals, forming in resorption embayements. Its brownish interference colour indicates that it is probably a Mg–chlorite.

Talc is hypidiomorphic, often deformed (kink–banded) and its size ranges from 0.1 mm to 0.5. It is absent in some parts of the drilled sequence but may be the main rock–forming mineral in other places, thus it is not limited to the shear zones (c.f. with SZEDERKÉNYI, 1974a,b and PAPP, 1989). During the serpentinization process talc forms from enstatite, suggested by its textural position, as it can be found on the periphery of the enstatite crystals in the ultramafic rocks (*Fig. 6*). Rarely it occurs together with olivine or opaques. Talc can also be generated by CO_2 metasomatism of serpentine minerals (NALDRETT, SCHANDL, 1992). In this case talc occurs together with carbonates (*Fig. 7*). The development of talc–bastites demonstrates that serpentinization is a complex, multi–stage process.

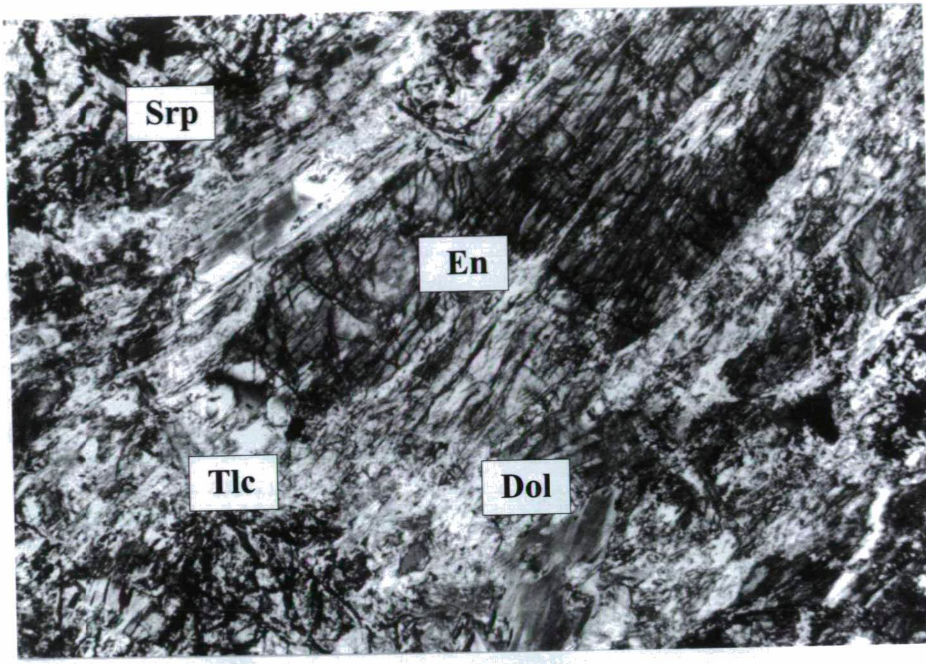

Fig. 6. ÁGK–7084 sample. Serpentinised grain of the enstatite surrounded by talc, +N, 50x.

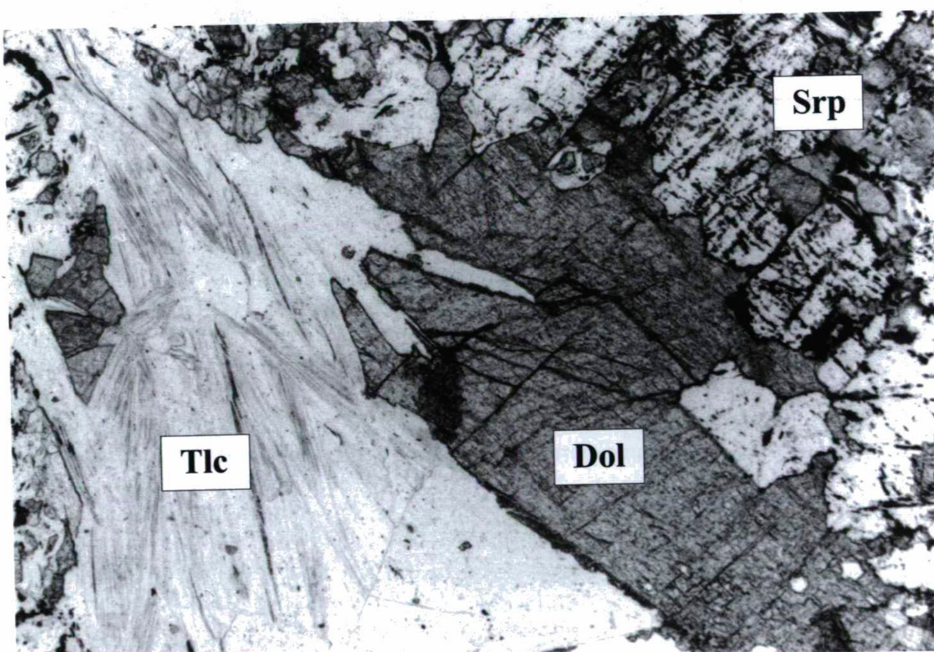

Fig. 7. No. 400412 sample. Talc–carbonate assemblage of CO_2 metasomatism from 79.7 m, |N, 50x.

The carbonate grains can be found between the relic minerals of the ultramafic rocks and in two different textural positions in the serpentinites. Carbonate staining (EVAMY, 1963) has revealed that the examined carbonate grains are low Fe–bearing dolomite. The individual grains and aggregates are characteristic of the ultramafic rocks where they often engulf serpentine minerals and enstatite. Fine grained, diffused carbonate can be seen in the mesh centre and along the central parting. As mentioned earlier, carbonate can also be detected in the veins.

Ultramafic rocks

Between 78–90 m in the Gyód–2 borehole several foliated, relic mineral–bearing, light–grey lenses and strings can be found. These are also ultramafic rocks but they do not form a continuous mass but rather appear as sheared lenses, enclosed in the serpentinites (*Fig. 3e*). The main rock–forming minerals here are enstatite, olivine, serpentine minerals, Mg–chlorite, talc and dolomite. Based on grain size, two types of ultramafics can be distinguished: one is a dominantly fine grained, relic enstatite and olivine–bearing rock and the other is a coarse grained ultramafic rock. The original igneous textures can be no longer recognised in these rocks because it has been obliterated during serpentinization.

Enstatite found in these rocks is hypidiomorphic, often shows undulatory extinction and is sheared, caused by deformation. Its size ranges from 0.2–0.5 mm in the fine grained type (*Fig. 8*). Elongated, columnar enstatite of 1–4 cm size characterises the course grained type. Enstatite often composes monomineralic layers or lenses which might reflect the original feature of the ultramafic rock (COLEMAN, 1979), but can also be the effect of serpentinization. Fresh olivine is rare because it is less resistant than enstatite, consequently, the description of its original textural features is problematical. Olivine alters along fractures and grain boundaries to form the easily recognisable pseudomorphs, composed of mesh and hourglass textures (*Fig. 8.*). Xenomorfic olivine remnants occur mostly in the centre of the mesh unit. Serpentinization of enstatite is similar to that of olivine; it begins at grain boundaries and fractures, then follows along cleavages and parting. However, it alters to χ–serpentine-bastite which usually appears in form of fibrous or nearly featureless plates. In the stages of alteration, talc is the first mineral phase which forms at the rim of enstatites but at the later stages it alters to serpentine (*Fig. 6*).

Between the ultramafic lenses and the surrounding serpentinite a courser grained band can be observed. This is composed of serpentine minerals (bastite), chlorite, talc, carbonate and some magnetite. This zone reflects the primary textural features of serpentinization. However, this band is rather narrow, compared with the mesh textured serpentinite and its mineral content is different. It is highly probable that almost the whole pseudomorphic texture has been modified.

Amphibole schists

Amphibole–bearing, light grey rocks are present at three intervals in the Gyód–2 borehole. The thickness of these rocks does not exceed 1 m but their position is not fully understood. On the basis of their mineralogy these rocks can be divided into tremolite and anthophyllite schists.

Tremolite schists occur at 82.9 and 112.2 m in the Gyód–2 borehole. The main rock–forming minerals here are tremolite, serpentine minerals, chlorite, talc and opaques. Tremolite occurs in form of hypidiomorphic, zoned needles, ranging between 0.4 mm and 2 cm and is imbedded into the fine grained serpentine matrix (*Fig. 9*). Its undulatory extinction is indicative of deformation. Tremolite often alters to bastite which consists of χ–serpentine. Talc occurs in small amounts in the contact with tremolite. Chlorite is zoned and its size reaches 1–2 mm. Occasionally it is surrounded by opaque grains. Carbonate can be found only in the veins.

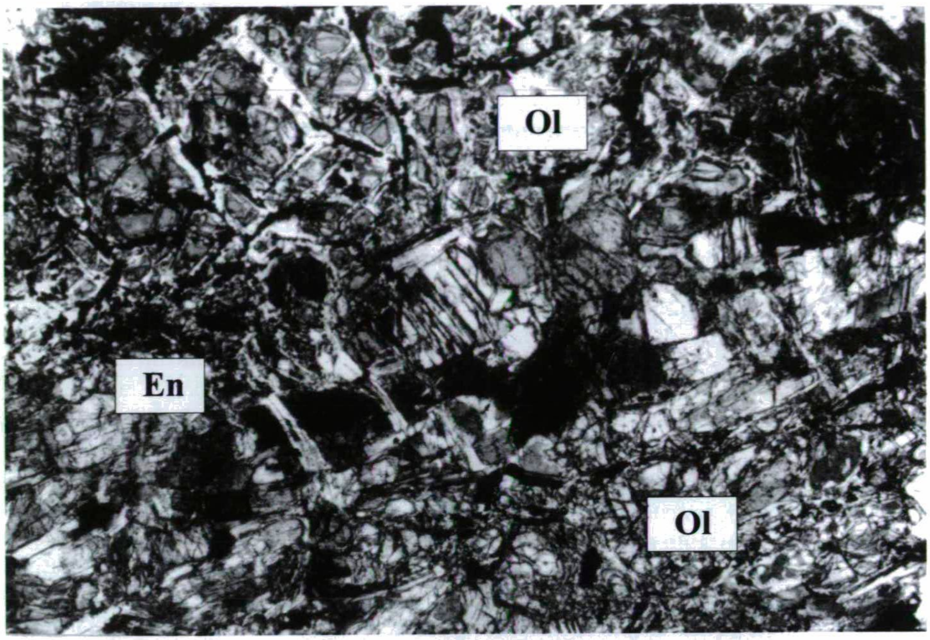

Fig. 8. ÁGK–7083B sample. The relic rock forming minerals in ultramafic rock, +N, 50x.

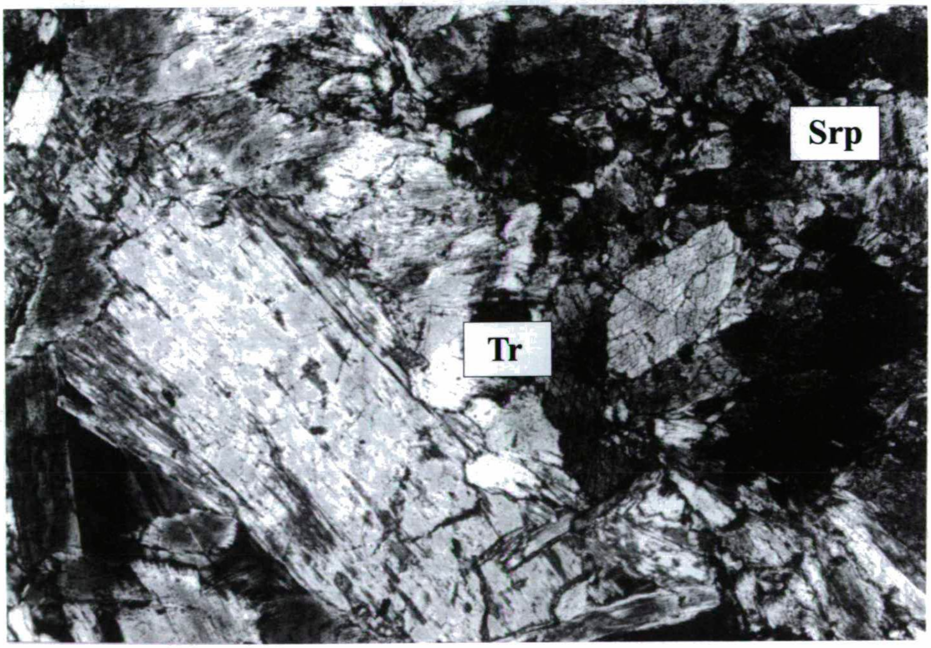

Fig. 9. No. 400381 sample. Tremolite schist from 112.3 m, +N, 200x.

Anthophyllite–bearing schists occur only at 105.0 m in the borehole and show two kinds of appearance: (i) as radiated or parallel 0.2–0.4 mm size fibrous crystals (*Fig. 10*), (ii) elongated, 0.5 mm–1.5 cm prismatic forms. Chlorite and talc are present in remarkably high amounts. The serpentine minerals are preserved as some kind of bastite, thus they are not as dominant here as in the other parts of the sequence. All of the rock–forming minerals are strongly deformed.

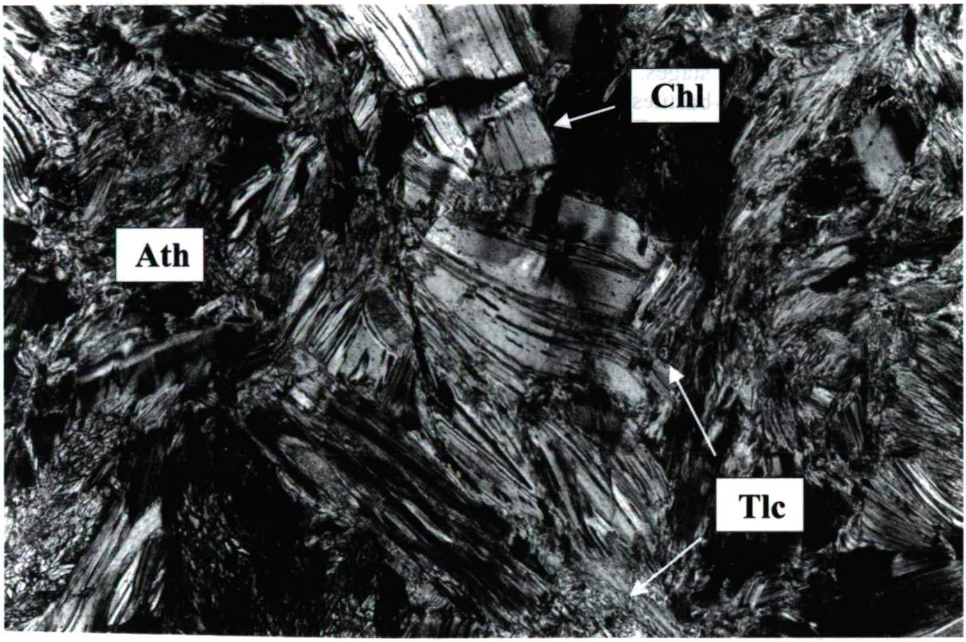

Fig. 10. No. 400389 sample. Anthophyllite schist from 105.0 m, +N, 100x.

SUMMARY

The principal rock types of the Gyód serpentinite complex are serpentinite, ultramafic rocks and tremolite and anthophyllite schists. The main rock–forming minerals of the ultramafics are enstatite and olivine. Other common minerals of ultramafic rocks are not present in the examined complex. Such a simple mineral composition indicates that the examined ultramafic rock is a harzburgite which, presumably, was also the protolith of the serpentinite. Harzburgite was derived from a depleted oceanic mantle, a conclusion made on the basis that it contains only enstatite and olivine whereas Ca and Al–bearing minerals (such as clinopyroxene, plagioclase, spinel, garnet) are absent. However, detailed geochemical analyses are necessary to support this statement.

Resulting from serpentinization and a subsequent recrystallization, generated by a metamorphic event, the primary textural features of the ultramafics can be no longer recognised. During the serpentinization process enstatite and olivine altered to serpentine